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13. ABSTRACT *(Maximum 200 words)*

The overall goal of this effort was to use a hierarchy of process-oriented numerical modeling studies to study the role played by a continuum of bottom bumps on flow over the continental shelf. Observed cross-shelf currents over the shelf tend to have higher amplitudes and shorter length scales than can be accounted for by existing models. The approach here was to ask whether model experiments could produce realistic (in terms of amplitude and statistical quantities such as length scales) cross-shelf currents under reasonable conditions. The primary results obtained from the study were obtained from a barotropic, nonlinear model, and the results are encouraging but incomplete in that density stratification was not included.

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Topographic Influences on Shelf Circulation

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Long-Term Goals:

The long-term goal of this project is to understand how extensive irregular bottom topography on the shelf and slope determines the statistics of coastal flow fields. Specifically, observations show that cross-shelf currents (on time scales longer than a day) are energetic and spatially incoherent. This fact has not been explained to date, even though we have a reasonably good dynamical representation of coastal sea level and alongshore flow characteristics. Although there are several possible mechanisms to explain the cross-shelf flow, this activity focuses on the possibility that a realistic continuum of bottom irregularities, in the presence of a coherent alongshore flow, can act to generate the observed properties.

Scientific Objectives:

The objective of this effort is to establish whether bottom topography is important for this problem, and what degree of physical complexity is required to explain the observed flow properties. The properties to be rationalized are the:

1) the O(2–8 cm/sec) amplitudes of observed subtidal cross-shelf flows, and
2) the relatively short, O(1–15 km), correlation length scales normally associated with these flows.

Characterizing physical complexity means establishing, for example, how important nonlinear or baroclinic effects are for obtaining correct results.

Approach:

The overall approach is to use a sequence of idealized numerical calculations to study how topographic irregularities generate cross-shelf flows. This work is to be executed by a graduate student as part of his thesis research. Initially, a linear barotropic model forced by an oscillating spatially uniform wind was considered. An irregular, bottom topography was used throughout the model, and the results were studied with respect to the interior (below the surface Ekman layer) cross-shelf flow. Calculations were then made with a nonlinear model. In the longer term, a

nonlinear, stratified model is envisioned in order to study the effect in a very realistic setting where dispersion properties of coastal-trapped waves can be highly modified. Nonlinearity is important because even weak flows with short spatial scales could have substantial relative vorticities.

Work Completed:

The linear barotropic study has been completed, but it did not lead to any publication, since it was found that the growth of small-scale motions quickly led to nonlinear conditions that required a numerical model for accurate solutions.

The nonlinear barotropic problem has thus been the focus of our efforts. This work led to a Master's thesis (Osychny, 1997) that may result in a publication. The work consisted of a sequence of numerical model runs using different topographies, forcing time scales, bottom friction values, etc. Results could be explained qualitatively in light of Hart's (1990, *J. Fluid Mech.*, 67, 437–455) quasigeostrophic time-dependent lee wave model.

A secondary effort involved developing a general theory for low-frequency island-trapped waves, and how they are excited by winds and ambient flow patterns. Theory was compared to current and sea level results from off Bermuda (Brink, 1997).

Results:

Including nonlinearity in the problem of time-dependent alongshore flow over irregular topography allows the generation of shelf lee waves. These waves can be generated either when the phase speed of the wave is equal and opposite to the ambient flow or when a forcing frequency harmonic matches a lee wave natural frequency. Since the flow is varying in time (periods of 2-20 days), the first condition (matching phase speeds) changes continually with time. Nonetheless, the strongest response occurs when the ambient alongshore flow is at its maximum, and is thus sustained at a fairly constant value for a few days (at lower frequencies, at least). The resulting flow field results in a satisfying degree of complexity in the cross-shelf flow patterns. The amplitude and spatial scales of the cross shelf flow agree reasonably with observations. Because the conditions for generating lee waves depend critically on free-wave phase speeds, and these speeds depend strongly on density stratification, it is difficult to say how well these results should carry over to the real ocean. Since stratification tends to reduce the dispersive nature of these waves, it seems likely that the barotropic results will prove to be an upper bound on the importance of topography for generating observed cross shelf flows.

The theory of low-frequency island-trapped waves (with realistic topography and stratification) allows estimation of the wave resonant frequencies, frictional damping and forcing by winds or ambient currents. The model reproduces Hogg's (1980, *J. Phys. Oceanogr.*, 10, 1353–1376) gravest resonance and resonance quality. Wind-driven currents do not appear to be very important for small islands, but are likely be more important for large islands. For large-scale ambient currents, their pressure signal should reach the island's coast unattenuated.

Impact/Implications:

On continental margins, cross-shelf gradients of most scalar quantities, such as temperature, dissolved nutrients or suspended sediments, tend to be much stronger than alongshore gradients.

This in turn means that cross shelf flows tend to be disproportionately important for determining net transports because transports vary as the product of velocity times the gradient. Thus, it is important to understand cross-shelf flows. It would be useful, therefore to be able to explain the origin of cross-shelf velocities and to define how sophisticated and refined models need to be to obtain realistic results.

Transitions: None

Related Projects: None

References:

Brink, K.H., 1997: Island-trapped waves, with application to observations off Bermuda. In preparation.

Osychny, V.I., 1997: Influence of bottom topography on cross-shelf circulation forced by time-dependent winds. Master of Science thesis, MIT/WHOI Joint Program, 101pp.